THE INFINITY
OF
THE STARRY UNIVERSE.

J. L. ADAMS.

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BY

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INTRODUCTION.

THE subject of the Infinity of the Starry Universe is closely connected with the question, What is the Milky Way? My book on the Milky Way published in June, 1905, has so far elicited no public comment in astronomical circles so far as I am aware, and this silence is capable of two different interpretations; either the evidence I adduced is unanswerable or else it is thought unworthy of serious notice. I am not justified in concluding that astronomers are averse to making the honest admission that the views they held about the Milky Way are erroneous, and I am thus obliged to conclude that my explanation of it is not regarded seriously. I have therefore in the present book added some further evidence in support of my contention, and as the view generally held by astronomers about the Milky Way is that it represents a special zone or region of the heavens, I have endeavoured to make it clear that this special zone is of such an extraordinary character that it has the enormous width of considerably over a thousand light years in the far distance, while converging on all sides towards the earth, till it becomes narrowed into a space immediately round the earth which is comparatively insignificant. The earth is in fact the central spot from which this special region or zone radiates, in effect, in all directions, growing gradually wider and

wider as it extends away into the far distance, its width being proportionate to the distance from the earth; being represented by a couple of light years, at most, at the distance of the nearest star, α Centauri, and gradually widening till it represents considerably over a thousand light years at the distance of the Milky Way luminous stream. If this idea of the character of the Milky Way zone be realized for the fact it is, a fact easily verified, there ought to be little or no difficulty in arriving at the conclusion as to the local origin of the influence which produces it, viz., the denser portion of the earth's shadow.

THE AUTHOR.

March, 1906.

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CHAPTER I.

The View generally held by Astronomers of the Finiteness of our Stellar System.

It appears to be generally accepted by astronomers that the stars which we see around us in the heavens do not belong to one stellar system extending throughout infinite space; but, while it is contended that the stars which surround us are finite in number, it is conceded by some that there may be other stellar systems, beyond our ken, and lying outside the boundaries of that to which our sun belongs. This is a safe and prudent reservation to make, seeing that we can know nothing of what is beyond all possibility of observation, but it appears antagonistic to the argument on which the conclusion that our stellar system is of finite dimensions is based. This conclusion is not arrived at merely because of the seeming decrease in the numbers of stars in the far distance, but is a deduction based mainly on a theory, the theory of the non-extinction of light in traversing space. The argument leading to this deduction is set forth in various astronomical works, among the latest being The Concise Knowledge Library's "Astronomy," published in 1898, and Professor S. Newcomb's work "The Stars: A Study of the Universe," published in 1901, and the latest (10th) edition of the Encyclopedia Britannica in the article on Astronomy. As this article is over the initials S. N. it may be presumed it is by Professor Newcomb.

In The Concise Knowledge Library's "Astronomy" the subject is dealt with by Mr. J. E. Gore, F.R.A.S., in the chapter on the "Construction of the Heavens" (page 543), and the argument is set forth thus:—

"But in addition to the conclusive evidence as to the limited number of the visible stars derived from actual observation and the results of photography we have indisputable evidence from mathematical considerations that the number of the visible stars must necessarily be limited. For were the stars infinite in number and scattered through infinite space with any approach to uniformity, it may be proved that the whole heavens would shine with the brightness of the sun. As the surface of a sphere varies as the square of its radius, and light inversely as the square of the distance (or radius of the star sphere at any point) we have the diminished light of the stars exactly counterbalanced by the increased number at any given distance. For a distance of, say, ten times the distance of the nearest fixed star, the light of each star would be diminished by the square of 10 or 100 times, but the total number of stars would be 100 times greater so that the total star light would be the same. *This would be true for all distances.* The total light would therefore, by addition, be proportioned to the distance and hence for an infinite distance we should have an infinite amount of light. For an infinite number of stars, therefore, we should have a continuous blaze of light over the whole surface of the visible heavens. Far from this being the case, the amount of light afforded by the stars on the clearest nights, is on the contrary, comparatively small, and the blackness of the background, 'the darkness behind the stars' is very obvious. According to Miss Clerke (System of the Stars, p. 7) the total light of all the stars to magnitude 9½, is about one-eightieth of full moonlight. M. G. l'Hermite found for the total amount of starlight one-tenth of moonlight, but this estimate is evidently too high. Assuming the sun's brightness as 28 magnitudes brighter than a star of the first magnitude, and Zollner's estimate that sunlight is 618,000 times that of moonlight, I find that the total light of the stars to magnitude 9½ as stated by Miss Clerke would be equivalent to the combined light of about 320,000 stars of the sixth magnitude, or 3,200 stars of the first magnitude. Even taking M. l'Hermite's high estimate of one-tenth of moonlight, the total starlight would be represented by 25,600 stars of the first magnitude."

In Mr. Gore's argument it will be observed it is assumed that the calculation applies "to all distances." The authority for this assumption is not stated and is, perhaps, taken to be well known, and I therefore presume it to be the theory which Professor Newcomb speaks of as the theory of the non-extinction of light in traversing space.

It will be noticed also that Mr. Gore speaks of indisputable evidence from "mathematical considerations" that the number of the "visible" stars must necessarily be limited. It seems strange to have to rely on mathematical considerations to determine what is the number of "visible" stars. Visible stars are, of course, those we can see, and they might, therefore, with some trouble, be

counted, or the numbers estimated. Perhaps Mr. Gore is relying on the theory as evidence that if the stars exist at all they must be "visible" no matter how distant they may be, and in that case it is the theory to which he looks for support to his "mathematical considerations."

In the article in the Encyclopedia Britannica, which I take to be Professor Newcomb's, there is also the same assumption that we should continue to receive light from stars, no matter how distant they might be; and the authority for this assumption is likewise omitted, but as the argument is more fully given in Professor Newcomb's book in the chapter on the "Structure of the Heavens," I quote here what he has to say on the subject:—

"The first question we have to attack is that of the extent of the universe. In its immediate and practical form, it is whether the smallest stars that we see are at the boundary of a system, or whether more and more lie beyond to an infinite extent. This question we are not yet ready to answer with any approach to certainty. Indeed, from the very nature of the case, the answer must remain somewhat indefinite. If the collection of stars which forms the Milky Way be really finite, we may not yet be able to see its limit. If we do see its limit, there may yet be, for aught we know, other systems and other galaxies, scattered through infinite space, which must for ever elude our powers of vision. Quite likely the boundary of the system may be somewhat indefinite, the stars gradually thinning out as we go farther and farther, so that no definite limit can be assigned. If all stars are of the same average brightness as those we see, all that lie beyond a certain distance must evade observation, at least as individual stars, for the simple reason that they are too far off to be visible in our telescopes.

"There is a law of optics which throws some light on the question. Suppose the stars to be scattered through infinite space in such a way that every great portion of space is, in the general average, about equally rich in stars. Then imagine that, at some great distance, say that of the average stars of the sixth magnitude, we describe a sphere having its centre in our system. Outside this sphere, describe another one, having a radius greater by a certain quantity, which we may call S. Outside that let there be another of a radius yet greater by S, and so on indefinitely. Thus we shall have an endless succession of concentric spherical shells, each of the same thickness, S. The volume of each of these regions will be nearly proportional to the square of the diameters of the spheres which bound it. Hence, supposing an equal distribution of the stars, each of the regions will contain a number of stars increasing as the square of the radius of the region. Since the amount of light which we receive from each individual star is as the inverse square of its distance, it follows that the sum-total of the light received from each of these spherical shells will be equal. Thus, as we include sphere after sphere, we add equal amounts of light without limit. The result of the successive addition of these equal quantities, increasing without limit, would be that if the system of stars extended out indefinitely the whole heavens would be filled with a blaze of light as bright as the sun.

"Now, as a matter of fact, such is very far from being the case. It follows that infinite space is not occupied by the stars. At best there can only be collections of stars at great distances apart.

"The nearest approximation to such an appearance as that described is the faint, diffused light of the Milky Way. But so large a fraction of this illumination comes from the stars which we actually see in the telescope that it is impossible to say whether any visible illumination results from masses of stars too faint to be individually seen. Whether the cloud-like impressions which Barnard has found on long-exposed photographs of the Milky Way are produced by countless distant stars, too faint to impress themselves individually even upon the most sensitive photographic plate, is a question which cannot yet be answered. But even if we should answer it in the affirmative, the extreme faintness of the light shows that the stars which produce it are not scattered through infinite space; but that, although they may extend much beyond the limits of the visible stars, they thin out very rapidly. The evidence, therefore, seems to be against the hypothesis that the stars we see form part of an infinitely extended universe.

"But there are two limitations to this conclusion. It rests upon the hypothesis that light is never lost in its passage to any distance, however great. This hypothesis is in accordance with our modern theories of physics, yet it cannot be regarded as an established fact for all space, even if true for the distances of the visible stars. About half a century ago Struve propounded the contrary hypothesis that the light of the more distant stars suffers an extinction in its passage to us. But this had no other basis than the hypothesis that the stars were equally thick out to the farthest limits at which we could see them. It might be said that he assumed an infinite universe, and, from the fact that he did not see the evidence of infinity, concluded that light was lost. The hypothesis of a limited universe and no extinction of light, while not absolutely proved, must be regarded as the one to be accepted until further investigation shall prove its unsoundness.

"The second limitation arises from the possible structure of an infinite universe. The mathematical reader will easily see that the conclusion that an infinite universe of stars would fill the heavens with a blaze of light, rests upon the hypothesis that every region of space of some great but finite extent is, on the average, occupied by at least one star. In other words, the hypothesis is that, if we divide the total number of the stars by the number of cubic miles of space, we shall have a finite quotient. But an infinite universe can be imagined which does not fill this condition. Such will be the case with one constructed on the celebrated hypothesis of Lambert, propounded in the latter part of the eighteenth century. This author was an eminent mathematician who seems to have been nearly unique in combining the mathematical and the speculative sides of astronomy. He assumed a universe constructed on an extension of the plan of the solar system. The smallest system of bodies is composed of a planet with its satellites. We see a number of such systems, designated as the Terrestrial, the Martian (Mars and its satellites), the Jovian (Jupiter and its satellites), etc., all revolving round the sun, and thus forming one greater system, the solar system. Lambert extended the idea by supposing that a number of solar systems, each formed of a star with its revolving planets and satellites, were grouped into a yet greater system. A number of such groups form the great system which we call the galaxy, and which comprises all the stars we can see with the telescope. The more distant clusters may be other galaxies. All these systems again may revolve around some distant centre, and so on to an indefinite extent. Such a universe, how far so ever it might extend, would not fill the heavens with a blaze of light, and the more distant galaxies might remain for ever invisible to us. But modern developments show that there is no scientific basis for this conception, attractive though it be by its grandeur.

"So far as our present light goes, we must conclude that, although we are unable to set absolute bounds to the universe, yet the great mass of stars is included within a limited space the extent of which we have as yet no evidence. Outside of this space there may be scattered stars or invisible systems. But if these systems exist, they are distinct from our own.

"The second question, that of the arrangement of the stars in space, is one on which it is equally difficult to propound a definite general conclusion. So far, we have only a large mass of faint indications, based on researches which cannot be satisfactorily completed until great additions are made to our fund of knowledge."

It will be observed that Professor Newcomb is careful to say that he does not regard the hypothesis of a limited universe and no extinction of light as absolutely proved, and he mentions a contention against the conclusion of finiteness based on the possibility of the structure of an infinite universe under certain conditions; but he concludes "that the great mass of stars is included within a limited space (of) the extent of which we have as yet no evidence. Outside of this space there may be scattered stars or invisible systems. But if these systems exist they are distinct from our own."

Sir John Herschel and Mr. Proctor essayed separately the designing of an infinite stellar universe which would not be amenable to the conditions imposed by the non-extinction of light theory, and Mr. Proctor tells in his book "Other Worlds Than Ours" how his views and those of Sir John Herschel had coincided.

The task I propose to undertake is, I think, of a more simple character than would be an attempt to devise any arrangement of the stars which would result in showing an infinite starry universe, even if I were unfettered by any condition such as the non-extinction of light in traversing space. I prefer to challenge the idea of the necessary conditions of infinity which is presented to us by our fellow mortals and to endeavour to show that this idea is defective. It must be understood, however, that while I propose to show that there is no indication of finiteness so far as we are able to judge, or of any limitation of the starry system to which our sun belongs, I do not propose to attempt to show that the stars extend infinitely, simply because such a condition as infinity is impossible of proof. On the other hand as we cannot grasp the idea of infinity in its entirety, any attempt to prescribe certain non-existing conditions as being necessary features of infinity may possibly be found defective in its appreciation of the difficulties of the subject.

Professor Newcomb's cautious reservation as to the non-extinction of light theory not being absolutely proved, seems to suggest a doubt on his part as to the soundness of the basis on which the conclusion is arrived at that the stars do not extend infinitely. Indeed, it does seem strange that so important a conclusion should be based on what is merely a theory, and a theory which, when applied to distances outside our powers of observation, is incapable of verification, while on the other hand, so far as our ordinary mundane experience of the behaviour of light enables us to judge, the evidence against the theory is irresistible; and if we turn to the stars we have the incontestable fact before us that distance diminishes their light to such an extent that only a comparatively small number of them can be seen with the naked eye. The whole number visible to the unaided sight is about seven thousand, while telescopes reveal that, as Professor Newcomb says, "The stars are to be counted by hundreds of millions."

Some of these stars which are thus invisible to the naked eye are comparatively near to us. Llalande 21185 and 61 Cygni, for instance, are the second and third nearest stars to us in the sky. Here then are instances of absolute extinction of these two stars' light so far as our naked sight is concerned, and these stars are quite close to us on the stellar scale of distance. It is certainly not contended by any astronomer that distance does not diminish the light of stars—on the contrary it is accepted that as a general rule the brightness of a star is in proportion to its distance. If, then, the light diminishes with distance so that even comparatively near stars are extinct so far as our naked eyes can tell us, it would be thought that it must be beyond dispute that the greater portion of the light from such stars has become practically extinct, and that consequently at some more distant point the remaining portion of their light must also disappear from view, even when aided by the most powerful telescopes. There is a limit even to the power of telescopes when we come to deal with such distances as those of the starry regions.

The calculation, which is based on the theory of the non-extinction of light, assumes that if the stars extend infinitely the loss of light from each more distant star will be compensated for by the increased number of such stars and the justification alleged for this is that up to a certain point, which is within our powers of view, a certain small increase of light is obtained, and the theory is the basis relied on to prove that this increase of light would continue to come from stars, no matter how distant they may be, if they exist in unlimited numbers, with the

result that the increase of light would also be infinite. The paradoxical character of this contention seems to have been strangely lost sight of by those who gravely put it forward. On the one hand, on the evidence of our senses, the stars are gradually getting fainter and fainter with distance, and this evident diminution of light is accordingly admitted and allowed for in the calculation; but on the other hand the theory contends that the light is not affected by distance, no matter how great, and these two utterly irreconcilable propositions are attempted to be brought into one and the same calculation. We might accept one or the other of them, but certainly not both, and the proposition which will probably commend itself to our common sense will, I think, be that which is based on evident facts and not that which depends on the theory.

CHAPTER II.

THE THEORY OF THE NON-EXTINCTION OF LIGHT IN TRAVERSING SPACE.

The impasse at which we have arrived naturally suggests an enquiry into the basis of the theory. The data on which it rests are set forth in the Encyclopedia Britannica (vol. 14) article on Light, in the chapter on Geometrical Optics, (part b), and it may be well to reproduce them here, though I do not suppose the general reader will trouble to study them carefully. They have no doubt been examined by competent authorities well versed in mathematics and optical laws, and it is evident must have been accepted as incontrovertible. Now, I am certainly not lacking in respect for scientific achievement. No one can be more convinced than I am of the debt of humanity to science, but my respect is limited to actual ascertained facts, and does not extend to theories or dogmas which are either impossible of verification or are seemingly opposed to notorious facts. Some episodes in my experience have also engendered in me a certain degree of scepticism as to the invulnerability of mathematical demonstrations. It is not that the mathematics are in fault, but some factor in the proposition has been overlooked, or unduly estimated, with the result that the conclusion arrived at is unsatisfactory. Now, if we examine the demonstration on which the non-extinction of light theory is based, I think we will find that it supplies a further justification for mistrust of the infallibility of theoretical conclusions even when supported by mathematical illustrations.

The Encyclopedia Britannica's article is as follows:—

"GEOMETRICAL OPTICS.

"Rectilinear Propagation of Light.

"It is approximately true that, in any homogeneous medium, light moves in straight lines.

"(*b*) Another important consequence of this law is that if the medium be transparent the intensity of illumination which a luminous point can produce on a white surface directly exposed to it is inversely as the square of the distance.

"The word transparent implies that no light is absorbed or stopped. Whatever, therefore, leaves the source of light must in succession pass through each of a series of spherical surfaces described round the source as centre. The same amount of light falls perpendicularly on all these

surfaces in succession. The amount received in a given time by a unit of surface on each is therefore inversely as the number of such units in each. But the surfaces of spheres are as the squares of their radii,—whence the proposition. (We assume here that the velocity of light is constant in the medium, and that the source gives out its light uniformly and not by fits and starts.) When the rays fall otherwise than perpendicularly on the surface, the illumination produced is proportional to the cosine of the obliquity; for the area seen under a given spherical angle increases as the secant of the obliquity, the distance remaining the same.

"As a corollary to this we have the further proposition that the apparent brightness of a luminous surface (seen through a transparent homogeneous medium) is the same at all distances.

"The word brightness is here taken as a measure of the amount of light falling on the pupil per unit of spherical angle subtended by the luminous surface. The spherical angle subtended by any small surface whose plane is at right angles to the line of sight is inversely as the square of the distance. So also is the light received from it. Hence the brightness is the same at all distances.

"The word brightness is often used (even scientifically) in another sense from that just defined. Thus we speak of a bright star, of the question—When is Venus at its brightest? &c. Strictly, such expressions are not defensible except for sources of light which (like a star) have no apparent surface, so that we cannot tell from what amount of spherical angle their light appears to come. In that case the spherical angle is, for want of knowledge, assumed to be the same for all, and therefore the brightness of each is now estimated in terms of the whole quantity of light we receive from it. It is in this sense only that we use the word when we speak of Venus at its brightest; for if we take the former definition of brightness the solution of this once celebrated problem would be very different from that usually given. As the question, however, is an interesting one both in itself and historically, we give an approximate solution of it. The approximation assumes what is certainly not true, that the illuminated portion of Venus always appears uniformly bright, and of the same degree of brightness in all aspects.

Let a be the radius of the earth's orbit, b that of the orbit of Venus, δ the distance between the planets when Venus is brightest.

"Then if θ be the apparent angular distance of the earth from the sun as seen from Venus, the illuminated part of the disk of Venus as seen from the earth is

$$\frac{1 + \cos\theta}{2}$$

of the whole disk. Hence

$$\frac{1 + \cos\theta}{2\delta^2}$$

is a maximum,—with the obvious trigonometrical relation

$$a^2 = \delta^2 + b^2 - 2b\delta\cos\theta.$$

Substituting for $\cos\theta$, and putting the differential coefficient $= 0$, we have a quadratic equation of which the only admissible root is the positive one

$$\delta = \sqrt{3a^2 + b^2} - 2b.$$

From this the other quantities can be calculated.

"But another matter has to be taken into consideration when we apply the above definition of brightness in practice. For the aperture of the pupil is usually very much contracted when we look at a brightly illuminated sky or cloud. Thus there is a rough compensation which, to a certain extent, modifies the effect on the retina.

"Founded on the above is Cheseaux's celebrated argument about the finite dimensions of the stellar universe. For it is easy to see, as below, that if stars be scattered through infinite space, with average closeness and brightness such as is presented by those nearest us, and if stellar space be absolutely transparent, the whole sky should appear of a brightness like that of the sun. Cheseaux and Olbers endeavoured to show that, because the sky is not all over as bright as the sun, there is absorption of light in stellar space. This idea was ingeniously developed by Struve.

"Consider a small spherical angle ω. The number of stars included in it whose distances are between r and $r + \delta r$ from the earth is proportional to

$$\omega r^2 \delta r.$$

The whole amount of light received from such a portion of the sky must be therefore as

$$\omega \int_0^\infty dr,$$

provided that no star intercepts the light coming from another. This condition is unattainable, so that the conclusion is that the brightness is as great as it can be with the materials employed. Every portion of the background shines as if it were a star."

The groundwork of the argument it will be seen is in the statement:—

"It is approximately true that in any homogeneous medium light moves in straight lines."

Then follows the consequence (B):—

"If the medium be transparent the intensity of illumination which a luminous point can produce on a white surface directly exposed to it is inversely as the square of the distance."

And then comes the corollary:—

"The apparent brightness of a luminous surface (seen through a transparent homogeneous medium) is the same at all distances."

We see that in consequence (B) it is stated that the intensity of illumination decreases proportionately with the distance. This is a deduction which is consonant with our experience. The corollary maintains, however, that the apparent brightness is not affected by distance. It follows from this that if the intensity of the light is decreased by distance but the apparent brightness is not, then the brightness does not depend on the intensity of the light! Can we accept this as being in accord with common experience? Why do municipal authorities go to the trouble and expense of obtaining lamps of

a high degree of illuminating power, that is giving light of a high degree of intensity, if intensity be not a necessary feature of brightness? Why waste the ratepayers' money in the face of this dictum of high scientific authority?

As it is evident, however, that mere common-sense considerations appear to have no weight in the scale against the theory, we must return to the examination of the proposition on which the theory is based.

We see that the proposition is dealing with units of surface of a series of larger and larger spherical areas round a central luminous object. It is shown that the light from the central object, such as a star, passes through each spherical area in succession, and that each further spherical area thus receives only the same total amount of light as the smaller area which preceded it. The same amount of light has to be distributed over the continually increasing surface areas, so that each unit of surface in each successive larger spherical area gets a proportionately less share of the total light. Up to this point the demonstration proceeds quite satisfactorily, and shows a continual decrease of the *amount* of light received by a unit of surface of each more distant sphere, and in consequence B this continual decrease of the *amount* of light received is correctly interpreted as meaning a decrease of intensity. So far, then, we have it distinctly admitted that both the amount of the light received and therefore the intensity of the light decrease proportionately with the distance. But then we are confronted with the alleged corollary of this in the startling proposition that the "apparent brightness" is the same at all distances. If this be a correct deduction it, of course, indicates that the "brightness" does not depend on the amount of light received or on its intensity, which, of course, are practically the same thing. We are thus driven to discover what sort of brightness it is which can be independent of the decreased amount or intensity of its light.

The solution of the mystery will be found in the standard set up as the measure of "brightness." This is taken to be the amount of light falling on the pupil per unit of spherical angle subtended by the luminous surface. Distance decreases both the amount of spherical angle and the amount of light received in equal proportions so that the ratio of one to the other is preserved. The ratio being thus constant "at all distances" the measure of "brightness" remains also constant at all distances, and if we accept the ratio thus laid down as the measure of brightness we must accept the result

indicated by the demonstration. Although the amount of spherical angle of the luminous object may be gradually decreased by distance until the luminous object itself, with of course its spherical angle also, ceases to be visible at all, this is of no consequence as we know the amount of light only decreases proportionately, and the ratio being thus maintained, the fact that we may eventually see neither any fragment of spherical angle, *nor any light at all*, does not affect the calculation. The measure of brightness agreed upon, is simply the ratio of the one to the other, and as this is preserved and remains the same, at all distances, so also must the "brightness"!

It may possibly be contended that I am unwarrantably assuming the eventual total disappearance of the stars' spherical angle taking all its light with it, without the necessary evidence that this would take place. Let us then examine the matter a little further.

To the uninitiated a "spherical angle" may seem a peculiar expression in view of what is the ordinary idea of an angle, but it means "the angle made by the meeting of two arcs of great circles which mutually cut one another on the surface of a globe or sphere."

When we ask how is the extent of spherical angle arrived at in the case of a star, which is a mere point or spot of light, the explanation attached to the corollary tells us that "stars have no apparent surface so that we cannot tell from what amount of spherical surface their light appears to come. Therefore, the spherical angle for want of knowledge is assumed to be the same for all stars, and therefore the brightness of each is now estimated in terms of the whole quantity of light we receive from it."

We see that assumption is based on assumption. First the amount of light falling on the pupil per unit of spherical angle is assumed to be the measure of brightness. If it be asked how many units there may be of spherical angle, the reply is that it is not possible to measure them, so they are assumed to be the same in the case of all stars, and the light falling on the optic of an observer must then be assumed to be the whole light of the star and represents its brightness.

A diagram (No. 1) showing, according to the suggestion in the demonstration, a series of spherical areas surrounding a central luminous source, may make clear the nature of the demonstration.

S is a luminous centre, a star. At a distance of 10 light years from it is described the circle A, as representing the spherical area with a radius of 10 light years which is filled at that distance by the light radiated from the star. B.C.D. and E. are portions of circles representing four other spherical areas, each at a further distance of 10 light years and each therefore proportionately larger in area. The sphere represented by circle E has then a radius of 50 light years, and the light from the star, after passing through each spherical area in succession, has, when it reaches circle E, to be distributed over a spherical area having a radius of 50 light years. As there is only the same total of light to be distributed over each spherical area, it is easily seen how at every point on each larger area the light received must diminish. It is after this has been made quite clear by the demonstration that we are then confronted with the alleged corollary that, notwithstanding this evident diminution of light with distance, (or is it as the result of it?) "the 'brightness' remains the same at all distances." On the diagram the line drawn to the point T (Terra) from the star represents a line to the earth, and it may be readily realised how the share of light coming along the line to T diminishes with each more distant and larger area to be filled, and, therefore, how ludicrous is the finding that the brightness remains the "same at all distances."

The demonstration assumes that the light coming to an observer at T (the earth) represents the amount of light per unit of the unknown spherical angle subtended by the star, and that this constitutes the measure of "brightness." It is then of no consequence if the star be supposed to be 100 or 1000 light years from T instead of 50. The light coming along the line to T will continually be reduced the farther it travels, but as the assumed spherical angle of the star must also be proportionately reduced, the ratio of one to the other remains unaltered, and as this "ratio" is the measure of brightness, it is this artificial standard of brightness which remains unchanged and is the same at all distances." This artificial or fictitious brightness of course does not necessarily mean "visible" brightness, even though the expression used in the demonstration is "apparent" brightness. The demonstration has no visual organs and is not concerned with the visibility of the brightness, but merely in the maintenance of the ratio which has been adopted as "brightness," a ratio between two unknown quantities, viz., the assumed amount of light per unit of spherical angle and the assumed extent of this unmeasured spherical

angle; and, as this ratio is preserved intact, there is no ground for complaint against the mathematical conduct of the demonstration.

Now, with regard to my assumption that the spherical angle of a star would eventually disappear altogether from view taking all its light with it; we have seen that the explanation in the demonstration as to the assumed spherical angle is that "because stars have no apparent surface we cannot tell from what amount of spherical surface their light appears to come. Therefore, the spherical angle, for want of knowledge, is assumed to be the same for all stars, and therefore the brightness of each is now estimated in terms of the whole quantity of light we receive from it."

Our sun is a star and, at our distance from it, has a measurable luminous surface and consequently a measurable spherical angle. The luminous surface, as we can readily realise, would become smaller and smaller if we travelled away from the sun, and its spherical angle would, of course, be correspondingly diminished. The luminous surface would be gradually reduced until it became merely a spot of light and then a mere speck, and eventually would disappear altogether from view, taking all its spherical angle with it. If it be denied that this would be the case, it will not be denied, I suppose, that the stars are suns, and in their immediate vicinity their brightness is something like sunlight, and they would present, like the sun, a measurable extent of luminous surface and also of spherical angle. As the luminous surface and spherical angle and also the light of all the stars have, owing to their distance, evidently diminished from what I may call the sun stage, I would ask any who would deny the certainty of a star's eventual total disappearance at some further distance, if they will kindly explain at what point of distance from any sun or star does the theoretical phenomenon begin to operate which while it permits the conversion of the sunlight into bright star light and then into faint star light, yet keeps its brightness the same "at all distances."

Can it be claimed that there is some special charm about a spherical angle to prevent its disappearing from view in due course like any other object?

The finding that a star's brightness is the same at all distances is so opposed to all our experience that its acceptance by astronomers naturally suggests the question: "Does it really mean what it seems to mean?" Sirius is the brightest star in the heavens, but is also one of our nearest neighbours. Are we to understand that we would continue to see Sirius shining

as brightly as we do at present if we could remove ourselves from him to a distance of 100 light years? If not why not? And why is Sirius brighter than stars farther away from us, such as Canopus or Arcturus, which are admitted to be much larger and intrinsically much more brilliant than Sirius?

The thing is so preposterous that it is impossible to get away from the suspicion that the original perpetrator of the bit of mathematical humbug we have been considering was well aware of the character of the contention he had set up. There is a suspicious abruptness in the way the corollary is introduced, and its demonstration is characterised by a judicious brevity and an authoritative conciseness well calculated to compel conviction that the conclusion presented is clearly inevitable.

Its unprincipled author no doubt enjoyed the success obtained by his carefully prepared reductio ad absurdum argument; but he could never have expected that its prosperity would be other than fleeting; or that it could possibly survive, as it has done, more than one generation of eminent astronomers, so that the problem has gained the title of "celebrated" which the Encyclopedia applies to it.

The success of this problem is an interesting example of the fascination exercised upon the imagination of learned men by a scientific theory, and the fact that a theory may be seemingly opposed to common place or common sense notions does not appear to make it less attractive. We cannot take up any astronomical work without finding conclusions of some sort based on the evident decrease of light with distance, and it would not, therefore, be considered possible that a theory which flouts all ordinary experience and common sense would receive any mercy at the hands of practical astronomers. A theory, supported by a mathematical demonstration, may be an impregnable rock to the many, but it should not be expected to meet with reverential regard from those whose eminence as astronomers would suggest an ability to overhaul and expose any defects in the structure; and one is left wondering at the seeming hypnotic effect on the mental faculties which scientific theories appear to produce. Hypnotism is described in the Library Dictionary as "a kind of mesmeric sleep or somnambulism, a similar condition produced by *gazing at a very bright object.*"

Does this seem to suggest that prolonged observations of heavenly bodies may not be undertaken with impunity? Who can say?

CHAPTER III.

SOME ILLUSTRATIONS HOW LIGHT DIMINISHES WITH DISTANCE.

After our investigation into the merits of the non-extinction of light theory, I suppose it is not necessary to deal further with the contention that an infinite stellar universe would mean perpetual sunlight everywhere, but it may be interesting to quote some estimates given by Professor Newcomb regarding the light we receive from the sun and from the stars, as they show in unmistakable fashion not only how light diminishes with distance, but how this feature of the behaviour of light is fully recognised on the one hand by astronomers, while on the other hand they are building a finite stellar universe upon a theory which asserts that the brightness of a star remains the same at all distances.

Professor Newcomb tells us that the sun gives us 10,000,000,000 (ten thousand million) times the light of Sirius; 91,000,000,000 (ninety-one thousand million) times the light of a star of mag. 1; 9,100,000,000,000 (nine million one hundred thousand million) times the light of a star of mag. 6. Also that if the sun were removed from us to a distance represented by a parallax of 2.06, or about $1\frac{5}{8}$ light years, he would shine with the light of Sirius, and at a distance represented by a parallax of 0.68, or less than 5 light years, he would shine as a star of mag. 1. We see, then, that the sun's light, great as it is to us on the earth, would only be equal to that of Sirius if our solar chief were removed from us to a distance of $1\frac{5}{8}$ light years, whereas Sirius is 9 light years away. Taking the estimates just quoted as a guide, then if we had no sun, but if we had instead a ring round us in the sky, composed of ten thousand million brilliant Siriuses at equal distances from each other and each at a distance from us of only 9 light years, their united lustre would afford us a light equal to our sun's light. This is a fair example of the admitted effect of distance in diminishing light. The luminosity of Sirius is stated by Professor Newcomb to be thirty times as great as that of the sun.

But it should be noted that the sunlight afforded us by this ring of ten thousand million Siriuses would not extend also 9 light years into space on the other side of the ring, as it

would be spread over a larger area, and from this we begin to get some faint notion of what it means to fill space everywhere with the brilliance of sunshine.

Another illustration of the degree of diminution of light with distance is seen also in the quotation I have given in the beginning of this book from the Concise Knowledge Library's book on "Astronomy" showing that the total light we receive from all the hundreds of millions of stars around us is estimated as considerably less than full moonlight. The moon is an insignificant object compared with a star; but then it is alongside us.

There is, however, perpetual sunshine throughout space if the stars extend infinitely, but it is limited to the immediate neighbourhood of each star, and the light rapidly diminishes as it travels away from its source. Each star is, in fact, a sort of blazing islet in an ocean of subdued light, which must extend throughout space as it is constantly receiving contributions from all the stars around. Should we not, then, find in this ocean of subdued light a sort of neutral zone, at varying distances from the stars according to their brilliancy, and constituting a sort of universal light equilibrium? If we travelled towards our nearest star neighbour, α Centauri, we would, no doubt, reach a point where the light of the sun and that of α Centauri would be equal. This point would be at less than half the distance between us and α Centauri because that star is brighter than the sun, its luminosity being estimated by Professor Newcomb at 1.7, the sun's being taken as 1. The points where the light of Sirius and of α Centauri would equal that of the sun would possibly show a degree of light representing the general condition in space away from the immediate vicinity of the stars, which, numerous as they are, are, after all, but brilliant globes of light, separated by immense distances from each other in the vast expanse of space. The distance between any two of these brilliant lights is of such a character that it transcends all our experiences of distance and is, therefore, unrealisable.

It is easy to talk about perpetual sunshine everywhere throughout space, but when we bear in mind the estimates just quoted which, if anywhere near the mark, mean that at a distance of only 9 light years it would need 10,000 millions of brilliant Siriuses to give us the light of sunshine, it does not require much consideration to show how inconceivable would be the number of stars necessary to fill even that portion of

space which is occupied by the stars within our view with the brilliancy of sunshine. It is estimated that the stars we see in the far distance must be several thousands of light years away.

As a light equal to sunshine is no doubt provided in the near vicinity of all the stars where it is most needed, why should it be wasted on the probably untenanted regions of space further removed from the centres of light and life? Nature is not parsimonious in her gifts but a reasonable economy in the supply of light may be a feature even of her large programme.

But there is another important consideration, viz., that as light and radiant heat are now authoritatively stated to be one and the same thing, we would find it very inconvenient if our supply of light and, therefore, also of heat, were largely increased. The same objection that we would offer to any great increase of light and heat would apply also to the cases of any other sentient beings who may inhabit parts of space outside the solar dominions, and thus perpetual sunshine everywhere would mean the extinction of all life such as we know of. If there exist other beings whose constitution renders them independent of any consideration of heat or cold they are, of course, outside the limits of our acquaintance.

In view of the identity of light and radiant heat the theory of the non-extinction of light in traversing space suggests the question how we should receive an intimation from some learned person that we need not draw near a fire in order to get warm, because "the heat of a fire is the same at all distances."

CHAPTER IV.

WHAT EVIDENCE IS THERE THAT THE STARS DIMINISH IN NUMBER IN THE FAR DISTANCE?

Having, I think, sufficiently dealt with the argument against stellar infinity, which is based on the theory of the non-extinction of light in traversing space, we may now proceed to consider what actual evidence there is to show that the stars are diminishing in number in the far distance. Professor Newcomb deals with the subject in the chapter on "The Progression in the number of Stars as the Brightness Diminishes" and says:—"While there is a difficulty in deciding the question because we have nothing like an accurate count of stars above the 9th, or at the most the 10th magnitude," yet "our general conclusion must be that up to the 11th magnitude there is no marked falling off in the ratio of increase even near the poles of the galaxy." He adds "that the question where the series begins to fall away is still an undecided one," and "the background of the sky itself is by no means black."

We see that up to the 11th mag. there is no falling off in the rate of gradual increase in the numbers of the stars, even in the seemingly barest region of the sky, viz., that farthest from the Milky Way; and when it is considered that stars of 6th mag. are the farthest visible to the naked eye, and that two of the nearest stars to us, Llalande 21185 and 61 Cygni, are only visible in a telescope, it should be evident that at such a distance as that taken to be representative of stars of 11th mag. we are fast reaching a point when stars of inferior brightness will be invisible even in a telescope. The faintest stars shown by the Great Lick telescope are classed as of 17th mag. and the estimates of the total number of stars visible vary very considerably. Professor Newcomb, in his summary of conclusions says:—"The total number of the stars is to be counted by hundreds of millions." He also says:—"The stars differ enormously in their actual luminosity. Some are thousands or tens of thousands of times more luminous than the sun, others only one-hundredth or one-thousandth as luminous."

With this great difference in luminosity it is only reasonable to expect that in the far distance only exceptionally bright stars will be visible, especially when we remember that the far

distance in this case reaches to thousands of light years, and that our sun, if removed to a distance from us of less than 50 light years would be invisible to the naked eye. At any great distance then it is only reasonable to find an apparent considerable falling off in the number of stars visible; but this, of course, would not be proof that the total number is diminishing, but merely that we can only see the exceptionally bright stars.

There is one conclusion of Professor Newcomb's which it is difficult to agree with. He says:—

"That collection of stars which we call the Universe is limited in extent. The smallest stars that we see with the most powerful telescopes are not for the most part more distant than those a grade brighter, but are mostly stars of less luminosity situate in the same regions."

Now, as no one is able to say what is the distance of a star which is so far away as to be beyond all possibility of measurement, this assumption of the Professor's is open to challenge, as without any means of knowing the distance of a star, what reliable estimate can be formed of its degree of luminosity?

The questions of the number of the stars and of their distribution in space are closely related to the question: what is the Milky Way?

CHAPTER V.

THE MILKY WAY AND ITS RELATION TO THE QUESTION OF INFINITY.

In all the attempts made at charting the stars there is a certain feature which is very pronounced, viz., the gradual increase in the number of stars visible as the Milky Way Zone is approached. This is so well known that it is not necessary to say much here on the subject, but I may quote what Professor Newcomb says in regard to it in referring to some star charts by Schiaparelli.

He says:—"A study of the reproduction which we give will show how fairly well the Milky Way may be traced out round the sky by the tendency of those stars visible to the naked eye to agglomerate near its course. In other words were the cloud forms which make up the Milky Way invisible to us we should still be able to mark out its course by the crowding of the lucid stars towards it."

Then again, with regard to the fainter stars, he shows how the whole sky was divided by Schiaparelli into nine zones or regions, each 20 degrees in breadth. Region 1 having for centre the North Galactic Pole, region 9 having for centre the South Galactic Pole, and Region 5 was the central one of the Milky Way. The corrected density found for each region was:

Region	1,	star density,	2.78	per	degree.
„	2,	„ „	3.03	„	„
„	3,	„ „	3.54	„	„
„	4,	„ „	5.32	„	„
„	5,	„ „	8.17	„	„
„	6,	„ „	6.07	„	„
„	7,	„ „	3.71	„	„
„	8,	„ „	3.21	„	„
„	9,	„ „	3.14	„	„

The count included all stars up to magnitude 9.

It will be seen from this how gradual is the increase of the number of stars in the sky of various magnitudes as the Milky Way is approached till the maximum is reached in the

galactic zone itself, Region V, of the table. This gradual increase in the number of stars towards the Milky Way is, of course, the natural result to be expected from viewing the Milky Way as the product of the centre of density of the earth's shadow. The density of the shadow also, of course, must diminish gradually on either side of its centre, with the obvious result that fewer and fewer stars become visible, the greater visibility of the stars being dependent on the greater density of the shadow through which they are seen, with the result that faint stars in the galactic zone become visible, while equally faint stars, that is stars which may be quite as near and quite as bright intrinsically, are not seen outside the zone. Then again Professor Newcomb examines whether this tendency of stars of varying magnitudes to crowd towards the Milky Way extends to stars which have a sensible proper motion. Kapleyn's conclusion in regard to the Bradley stars was that those having a considerable proper motion, say more than 5" per century are nearly equally distributed over the sky, but that when we include those having a small proper motion, we see a continually increasing tendency to crowd towards the galactic plane. Professor Newcomb thinks this conclusion, so far as it concerns the stars with small proper motions, is unreliable, but his examination of it does not make this clear, as Auwer's observations which he deals with seem to confirm it; but the Professor arrives at the general conclusion that "stars with sensible proper motions and of various magnitudes are scattered uniformly over the sky and show little or no tendency to crowd towards the galaxy unless, perhaps, in the region near 19h of R.A.

In my book on the Milky Way I showed that of 39 stars having a parallax of 0".10 or over and, therefore, representing the nearest stars to us in the sky only twelve were in the Milky Way zone. This was evidence that the special brightness of the Milky Way zone was not owing to the nearness of its stars. The fact that the stars with sensible proper motions and, therefore, on that account probably near to us, are also distributed uniformly in the sky without special reference to the Milky Way, is further evidence to the same effect, because stars which are not far distant and which are, therefore, fairly bright are visible without the aid of the special density of the shadow. Then, again, Kapleyn's finding (though Professor Newcomb disagrees with it) that stars having only a small proper motion and probably, therefore, more distant than those with sensible motion, show a continually increasing tendency to crowd towards the galactic plane; is simply explained by the special

density under which they are seen, which brings them into view when similar stars, well outside the galactic zone, would not be visible.

The strange notions entertained about the Milky Way by astronomers have led to some fanciful attempts at indicating what is the shape of the stellar system, and the greater number of stars in the Milky Way region has been taken to indicate that it represents a sort of central arch from which the stars on either side gradually decrease in number towards what is called the galactic poles, and it is supposed that when looking towards these poles we are looking at the outside limits of the starry system to which our sun belongs.

In the introduction to my book on the Milky Way I stated that the first idea which seized upon me was the utter impossibility of our being able to see even the smallest arc of any circle extending round the universe, and I have accordingly prepared some diagrams which, I think, will indicate this very plainly while, at the same time, showing the local character of the Milky Way phenomenon.

In diagram No. 2 I have taken the sun, Sol, as the centre of a circle, or sphere, containing all the stars up to 6 magnitude, that is all our lucid stars. As we know the parallaxes of less than 100 stars, of which but 39 have a parallax of 0".10 or over, or 32 light years, while a parallax of 0".01 would represent 325 light years, I think I am justified in assuming that I am within the mark in taking the first sphere, that of Sol, which has a radius of 250 light years, as including most, if not all, of our lucid stars. The second sphere, whose central star I will call Pol, distant 500 light years east of Sol, will be assumed to contain a number of those stars of 7, 8, 9, and 10 magnitudes, which, as seen from the earth are in Sol's eastern sky from North to South. These stars will form Pol's lucid stars. The third sphere, that of Mol, will contain some of Sol's eastern stars of 11, 12, and 13 mag., forming Mol's lucid stars. The fourth sphere, that of Dol, will contain some of Sol's eastern stars of 14 and 15 mag., which are Dol's lucid stars. The fifth sphere Fol, will contain some of Sol's eastern stars of 17 mag., while the last sphere, that of Lol will contain as lucid stars the nearest of the stars forming part of the luminous stream of the Milky Way. The central star of each sphere is placed on an eastern extension of the Equinoctial, and each is distant 500 light years from its neighbour, so that from Sol to Lol represents a distance of 2,500 light years. It is not of consequence that the distances should

be anything like exact, but I think it will be allowed that I am within the mark in assuming 2,500 light years as representing the distance between us and the nearest of the remote stars of the luminous background of the Milky Way.*

Now, if we imagine ourselves removed to Pol what change will take place in our view of the heavens? As we approach any stars the spaces between them will open out, while on the other hand the stars we are receding from will close in behind us. The first thing, then, to be observed is that all the 7, 8, 9, and 10 mag. stars to east of Sol have spread over a larger extent of sky, the stars which were east-north-east as seen from Sol, will be found to have moved northward and westward, and those which were east-south-east will have spread to south and west, the whole thus becoming Pol's lucid stars. Some of these stars belong to the Milky Way zone as seen from Sol, but from Pol they will be seen to have left it and to have become spread over a large part of Pol's sky, because though the Milky Way luminous stream will have also become wider, it will not have widened sufficiently to retain these stars within its folds. As seen from Pol the lucid stars of Sol will all be found drawing towards the equinoctial line, the line on which we are travelling. This will have brought a certain number of them which were in the Milky Way zone, quite away from it and, of course, all those which were in the eastern zone of the Milky Way, as seen from Sol, will now be seen to west of Pol, while the luminous stream is still to our east.

As we continue our journey eastward a similar experience will be gone through—stars which, as seen from Sol are in the eastern Milky Way zone, will be gradually moved quite out of it and become further and further west of us as we travel, while the luminous stream itself will still remain to our east, but growing larger and larger as we approach it, while Sol's lucid stars will gradually become smaller in regard to the area they occupy in the sky, while the western portion of the luminous stream of the Milky Way is being lost to sight. It will have completely disappeared from view before we have reached Lol, and as seen from Lol such of the lucid stars of Sol as remain

*Professor Newcomb, in considering the distribution of stars in space makes the following estimates of the star contents of spheres of various radii:—

Radius	400R	will contain	8,000,000	stars.
,,	600R	,, ,,	27,000,000	,,
,,	800R	,, ,,	64,000,000	,,
,,	1000R	,, ,,	125,000,000	,,

He says:—"We may suppose that the actual number of non-galactic stars, visible and invisible, probably fall within the limits of the above numbers," and "we have no reason to believe that, away from the Milky Way, the stars extend far beyond the sphere 1000R, at whose boundary the parallax is 0".001."

It will be noticed that Professor Newcomb's estimate of 125 million stars does not include those in the Milky Way stream, and the boundary he estimates for the non-galactic stars he places at a distance represented by the parallax of 0".001, or 3,250 light years.

visible will be remote telegraphic specks forming a little group and all on and near the equinoctial line. When we have finally reached Lol we would be in the region of the nearest stars of the luminous stream, and these will form the lucid stars of Lol extending north, south, east and west. Shall we, then, have reached the boundary of the universe or should we find the same outlook everywhere as we do from Sol? All we know for certain is that in the faint luminous clouds of the Milky Way the stars are in countless myriads, and there can be no doubt that as we approached them they would open out on every side and also directly in front of us to such an extent that an extremely small section would cover as much space as do all the lucid stars we see from the earth. The dark and seemingly barren Coal Sack contains over 6,000 stars, or as many as can be seen with the naked eye in the whole sky from Sydney. There is not a particle of evidence to justify any contention that the stars are not as equally distributed everywhere throughout space, as they are in our vicinity, and it is safe to assume that in any part of the luminous stream of the Milky Way a section as large as the Coal Sack will contain more than 6,000 stars, because the luminous stream is still farther away from us than are the stars which are near enough to be counted in the Coal Sack. If we could travel to any part of the Milky Way we would certainly find ourselves surrounded by stars stretching in every direction, and can we say that we would then be nearer any boundary of our stellar system than we are upon the earth? Anyone stationed in the nearest part of the luminous stream of the Milky Way to our east would certainly have an immense extension of stars on the north and south of him along the galactic ring, and to his west he could not see further than we do to the east, that is, his view would reach to the sun and would not extend to the limits of our western view. Can we then say that there would be any limit to the stellar expanse to his east?

We have seen that as we travelled east from Sol stars in the foreground of the eastern part of the Milky Way were transferred to our west while the luminous stream itself remained to our east. This severance of the component parts of the Milky Way zone would continue until we reached the luminous stream itself. And not only would a certain number of those stars have been removed to our west but others will have been removed to our north and to our south because they would open out in all directions as we approached them to a much greater extent than would the luminous stream itself. When it is remembered that the special brightness of the Milky

Way is not confined to the luminous stream, but is characteristic of the stars of all magnitudes comprised in its zone, as evidenced by the quotations I have given from Professor Newcomb's book, and when it is realised that the stars in the foreground of the Milky Way will be moved quite out of the circle by a mere change in the observer's position, how is the special brightness they show to be accounted for except on the hypothesis that it is a special shadow effect which operates on them only when they remain in the position in which we view them from the earth and which is, therefore, simply a local influence.

It is interesting to note the puzzled efforts of astronomers to define what is meant by the Milky Way. When asked what it really comprises, where it begins and what stars belong to it they are unable to give any definite answer. But there ought to be no difficulty on the part of anyone who will take the trouble to study the sky in coming to the conclusion that the special brightness of the Milky Way belongs to its whole zone, and extends to all the stars in it from the nearest to the farthest, the lucid and fainter stars of the foreground as well as the luminous stream itself. Anyone not able to see this by looking at the sky will find it clearly set forth in astronomical works, showing how the actual course of the stream is indicated, even when it is not itself visible, by the great number of lucid stars in its region as compared with other parts of the sky, and then that this special brightness gradually diminishes on either side as the Milky Way is receded from. Professor Newcomb concludes thus his chapter on "The Structure of the Milky Way." "If we should remove from the sky all the local aggregations of stars, and also the entire collection which forms the cloud-forms of the Milky Way, we should have left a scattered collection continually increasing in density towards the galactic belt."

It seems strange that astronomers should have failed to draw the obvious conclusion of a special local influence at work to which all these observations of the Milky Way so clearly point.

In addition to the evidence given in my book on the Milky Way as to the central position the earth occupies in regard to it, we will reach a similar conclusion by considering the relative position of some of our nearest stars in regard to the galactic zone. There are two stars, Sirius and Procyon, which are near each other and also near us comparatively. Sirius is just under 9 light years and Procyon just under 11 years from us, and the distance separating the two stars is estimated at 5.3 light years. The stars are on opposite sides of the Milky Way

stream and near its edge. If we imagine Sirius removed a little more than a year further from us, and Procyon brought back a little less than a year, and then draw a line between the two new positions, it will give us a base line five years long for a triangle to include the earth and the two stars, with the earth as the apex. The centre of the base line will be 10 light years in a direct line from the apex, the earth. A triangle on these lines (see diagram No. 3) will retain for all distances this proportion between the length of the base line and the length of a line from the apex (the earth) to the centre of the base line, one being half the other. The transformation made in the position of the two stars will not affect their relation to the Milky Way beyond that the shortening the distance between them will bring each star a little closer towards the stream. (I am treating both stars as just outside the stream as shown in Peck's maps, but when the Milky Way stream is seen to advantage as I have seen it from an elevation of 3,000 feet it is sufficiently broad away from the immediate vicinity of the stars to include them both in its course, but just around them the brilliancy of the stars prevents the fainter light of the luminous stream being visible.) The zone then at Sirius and Procyon's adjusted distance is 5 light years in width, i.e., the length of the base line of the triangle. With the triangle extended to the distance of the Milky Way stream, which I am assuming is 2,500 light years away in a direct line from the earth, the base line will be half this length, i.e., 1,250 light years. The zone then of the Milky Way which at Sirius and Procyon's adjusted distance from us is represented by 5 light years in breadth is at the distance of the luminous stream 1,250 years in breadth. At a distance of 5 light years from the earth the zone will be represented by a breadth of $2\frac{1}{2}$ light years and, of course, it will continue to diminish until it is represented in the vicinity of the earth by an area which is insignificant. The stream is not at its broadest between Sirius and Procyon. It is, as shown in Peck's maps, much broader at Scorpio and Sagittarius, and we can thus realise what a huge area is represented by the stream there. It is also very broad at Argo, but is greatly broken up there by the influence of the many bright stars in that constellation. All round us in the sky the Milky Way stream represents an enormous area, but the zone must diminish greatly in breadth as it approaches the earth as we have seen it does in the direction of Sirius and Procyon. If we take the breadth of the zone at their distances as a general guide it will be represented by a similar triangle everywhere, having its apex at the earth,

and we can figure it as an enormous conical or wedgeshaped region of the sky, surrounding us on every side with its edge presented towards us, and with an enormous background, ever growing in width as it stretches away into the far distance.

The position of other near stars in relation to the Milky Way zone confirms this presentation of its real structural character. α Centauri $4\frac{1}{3}$ light years and 61 Cygni, about 8 years away, are near the middle of the zone, but it misses altogether Llalande 21,185, 7 light years away, which is between the other two in its distance from us. If we apply our triangular measure to these stars (see diagram No. 4) we find that at α Centauri the distance from the earth to the centre of the base line is $4\frac{1}{3}$ light years. The length of the base line of the triangle at α Centauri is then half this, or $2\frac{1}{6}$ light years, which thus represents the width of the zone at this point. α Centauri is near the central point of the base line. At 61 Cygni, distance 8 light years, the width of the zone will be 4 light years and 61 Cygni is also near the centre of the base. At the distance of Llalande 21,185, i.e., 7 light years, the zone would only be $3\frac{1}{2}$ light years in breadth, and we can then easily understand why this star, near as it is, can be so far outside the zone. Llalande 21,185 is in Ursa Major, and this constellation, which is well outside the Milky Way, contains no less than ten stars out of the whole thirty-nine in the heavens which have parallaxes of 0".10 or more, and which are, therefore, the nearest stars to us in the sky, and surround us on every side within a sphere whose radius is only 32 light years. Of all these thirty-nine stars only twelve are in the Milky Way zone. At the assumed distance of the luminous stream, 2,500 light years, the space between Sirius and Procyon would represent a breadth for the Milky Way zone of 1,250 light years, while at Scorpio and Sagittarius the space would represent about twice that area. We have seen that Professor Newcomb estimates that the non-galactic stars extend to a distance of 3,250 light years, and the Milky Way stream is beyond. With these figures as a basis the space between Sirius and Procyon would represent at the distance of the Milky Way stream a width of over 1,600 light years. With the enormous area which it is evident is comprised in the Milky Way zone in the far distance, we see how it must narrow as it approaches the earth when its zone in our vicinity only contains twelve out of the thirty-nine stars which are all within a distance from us of only 32 light years.

As there is nothing in the constitution of these twelve stars, so far as we know, to account for their inclusion

in the Milky Way zone, while their twenty-seven near neighbours are excluded, what conclusion as to the special brightness of all the Milky Way stars, the nearest as well as the farthest, can be formed on due consideration of all the facts than that it is the result of a special influence emanating from our immediate neighbourhood and forming a belt which necessarily only embraces a few stars in our vicinity, but a gradually growing number as the space enclosed within the belt represents a larger and larger area.

Is it reasonable to think that there can be a special zone of the heavens having a breadth in the far distance everywhere of considerably over a thousand light years and tapering to insignificance on every side of us as it approaches the earth?

NOTE.—At *a* Centauri the stream is much narrower than it is between Sirius and Procyon, and the indicated width of the zone at *a* Centauri is therefore proportionately less and would be really much short of the 2 1-6th light years I have allowed for it. At *a* Centauri's distance from us a similar extent of space to that which separates Sirius and Procyon would represent much less than 5 light years. The space separating *a* Centauri from Lalande 21,185, is estimated at only 9 light years, though they are on opposite sides of the heavens.

CHAPTER VI.

THE STRUCTURE OF THE UNIVERSE.

With regard to the question of the structure of the universe the diagrams Nos. 2, 5 and 6 will, I think, enable it to be realised what possibility exists of our seeing in all its dimensions any circle extending round the starry universe such as the Milky Way is taken to be. The farthest distance to which our view extends is in the Milky Way, where all possibility of seeing what may be beyond is blocked by clouds of faint light composed of myriads of stars. The circle I have drawn with Sol as its centre (diagram 5) has a radius of 2,500 light years and is supposed to represent the apparent boundary of our system as we see it extending to the luminous stream. It is of no consequence whether the distance is more or less than 2,500 light years. Arcs of circles with Pol, Mol, Dol, Fol, and Lol as centres indicate the eastern boundaries as they would be seen from those centres. If it be denied that we have any right to assume that the stars extend another 2,500 light years to the east of Lol it cannot on the other hand be asserted that they do not, and it must be admitted that they, at least, extend out to some unknown distance beyond Lol, that is beyond the masses of stars forming the luminous clouds of the Milky Way. It will be noted that each circle has its own north and south independent of that of Sol or of those of the other circles. Now, in addition to the extended boundaries to the east which are indicated by these circles, we would be justified in adding other circles north of Sol and Pol and the rest (see diagram 6) and this would mean a northern boundary still further north, and of course indefinitely further, than the northern boundaries seen from Sol, Pol and Co. Further similar circles could be added to the west and to the south as well as in other intermediate directions and these would show further indefinite extensions of the starry boundaries in all directions.

In considering the question of the reality of the apparent boundaries of the stellar system as we see them from the earth, it will be of service to keep in mind the relation in point of size of any area in the far distance to any area in our vicinity. If we imagine a circle drawn round the sky at the distance of a spot between Sirius and Procyon, 10 light years away from us,

the space between those two stars would be represented by an arc of the circle having a length of a little over 5 light years, whereas the same arc, that is an arc bridging the space between Sirius and Procyon, would, at the distance of the luminous stream of the Milky Way, represent a length of some 1,250 light years, that is 250 times greater, taking only a moderate estimate of the distance the luminous stream is from us. This will enable us to form some notion of how large an area any small spot in the far distance will represent, and how accordingly any small spot on the seeming boundaries would open out and extend in all directions if we could approach it till a seemingly insignificant range to north or south, east or west, or elsewhere, as seen from the earth would, in reality, represent an enormous distance.

To show how an enormous area in the far distance is represented by what seems but an insignificant spot in the sky, we have the evidence of the star clusters, expecially the cluster Omega Centauri. Over 6,000 stars have been counted in a photograph of this cluster and it is estimated it contains altogether about 10,000. Sir John Herschel described the stars as being of 13 and 15 magnitude. Whether they be of average size compared with those we see around us or smaller, it is evident the space occupied by 10,000 stars must be immense. To the naked eye, however, they form simply a spot of faint cloudy light, like a star surrounded with haze, and this apparent smallness of the space they occupy is evidence that their distance must be very great, while at same time showing how distance decreases the apparent area.

Though we cannot assert that the stars extend infinitely, there is nothing in our knowledge to justify any assumption that the sphere Lol is any nearer to any boundary of the starry universe, if there be one, than we are at Sol, and the same thing can be said with regard to the northern, southern and western or any other apparent boundaries. All that we know for certain is that in the far distance the stars become massed closer and closer, until finally, at any rate in the Milky Way, they are in clouds of faint light, and as the Milky Way extends around the sky on all sides, it is not difficult to realise that if we travelled towards it anywhere we would find the stars opening out to an indefinite extent as we approached, and we would be continually finding ourselves in a new central position surrounded on all sides by near and more distant stars just as we find ourselves on the earth. This is certainly what would happen if we could travel to any portion of the luminous stream

of the Milky Way, and what then is the justification for any assumption that these faint clouds of stars are the furthest limits, the Ultima Thule of the starry universe around us, instead of being simply the furthest limits of our powers of view?

It is natural, of course, for men, unconsciously perhaps, under the influence of the long accepted teaching that man and his earth are the central features of creation, to assume that our habitat is the centre of the starry system; but a very little study of the information we have gained as to the relative importance of our sun among the starry host, is likely to excite some suspicion in unbiassed minds that the other stellar luminaries may also have their own raison d'être in the Universal Plan; and that it is extremely doubtful that the hundreds of millions of stars around us, have been waiting for untold periods of time the advent of the comparatively newly arrived creature, Man, merely to shed their lustre on his abode. And is this self-glorified man all that might reasonably be expected of him with the experience he should have gained by this time from the wisdom, as well as the errors, of his predecessors? Does he not still seem to cherish in the mass the blood-thirsty instincts of the more ferocious of his relatives among the brute creation Look at what is happening even in this age of progress, superficial as the progress may be. We see the repeated onslaughts upon each other of both savage and so-called civilized communities, the reckless bloody attempts at revolution of oppressed and despairing multitudes, and around us everywhere, even among the more enlightened nations of the world, such love of, or trust in each other, as is indicated in their necessarily assiduous cultivation of all that appertains to the pride, pomp, and circumstance of glorious war. Surely there must be beings in other parts of the heavenly regions, if not on some of the members of our own solar system, who have advanced beyond our primitive stage.

It may be acceptable to our self-esteem to think that we occupy a central position in the universe, but if we judge of our importance by the proportions of our system, or the stellar rank of our solar chief, it is not quite satisfactory. There are about 7,000 stars altogether which are visible to the naked eye, including those in both hemispheres. Our sun, if removed to a distance represented by a parallax of 0".07 (less than 50 light years) would be a star of 6 mag. Stars of that magnitude are just visible to the naked eye. Professor Newcomb gives a list of all the stars which are near enough to have measurable parallaxes. There are sixty-nine in all, though some are doubtful, being very small. Of the sixty-nine there are fifty-five

which are comprised within stars up to mag. 6, and which are, therefore, visible to the naked eye. Of these fifty-five stars there are eighteen of magnitude 1, and the smallest, α Centauri, is larger than our sun. There are seven of mag. 2 with such small parallaxes and, therefore, so distant that they must all be larger or brighter, or both, than our sun or they would not be visible to the unaided sight. There are seven of mag. 3, of which five are brighter. There are eleven of mag. 4, of which four are brighter, and seven of mag. 5, which are all brighter, and five of mag. 6, of which two are brighter. Thus, of the total of fifty-five stars there are only thirteen which are not brighter than the sun. It may be assumed that the parallaxes of most of the naked eye stars that are measurable have been measured, and that the distance of the rest is so great that they must all be much brighter than our sun or they would be invisible to the naked eye. There are, then, of the whole 7,000 odd lucid stars, only thirteen which are not found to be brighter than the sun, and as we look out on the starry expanse we can reflect on this fact that of all the stars we see with the naked sight, all except about two in every thousand are superior in brilliancy and doubtless also in size to our luminary. The parallaxes of so few of the stars are measurable that we cannot tell what distance may separate us from the greater number of those we see with our naked eyes, not to speak of those only visible in telescopes. We know, however, that a certain number of the brightest stars enormously exceed our sun in size and brilliancy, and all the stellar luminaries are doubtless accompanied by their retinues of planets proportionate in size and splendour to the grandeur of their principals. If we then adopt the idea that man is the only representative of mind or intelligence throughout all these vast worlds, we would seem to have just cause for dissatisfaction that with so many magnificent mansions untenanted throughout the starry space, we should have been housed amid surroundings so little commensurate with our importance. There may be some consolation in the reflection that our dwelling place is not quite in the humblest rank, but this solace will only appeal to the modest few who may think we have scarcely as yet shown ourselves worthy of greater consideration.

The notion that from our little spot in space we are able to see the bounds of the starry universe and that it is limited to the area we see meeting around us in the far distance, enclosing us so that we naturally occupy the central position, is in its ingenuousness, akin to the idea that it would be possible

to draw a map of the earth from the data afforded by the view from the top of a ship's mast in mid-ocean, or from the top of some mountain. There is a biblical narrative which sets forth how the devil was able to show "all the kingdoms of the world" from the top of an "exceeding high mountain." Granting that "the world" had in this story the limited meaning of the then known world, it extended at least to Egypt, Greece and Rome in the West, and the "kingdoms of the world" thus represented a fairly large area. To see all these from the top of an exceeding high mountain was a considerable feat suggesting powers of vision beyond our mortal experience; and also suggesting, therefore, that it could, perhaps, have been accomplished without climbing any mountain. The satanic powers of vision are not, however, shared by mortals, and even a powerful telescope is limited in its range and we can only see straight ahead with it. We do not even know that the expanse of the universe is in a straight direction from us anywhere, although it appears to be so everywhere. When we see the ocean and sky meet on the horizon, or when we see the meeting of the earth and sky from the top of a mountain we do not think, in these days, that we are looking at the boundaries of Mother Earth. What better grounds have we for assuming that in the far distance where the stars crowd together in their closely packed masses presenting in the Milky Way part of the sky the appearance of clouds of faint light, we are looking at anything more than the visible boundaries of our connection with what may be, for aught we know to the contrary, an infinitely extending starry universe?

If we remained rooted to one spot on the earth, as the earth is practically confined to one spot in space, we would know nothing, of our own knowledge, as to the expanse of the earth, and would not easily comprehend how the bearings of distant places anywhere change in regard to us, and to each other, as we voyage in different directions from or towards them.

Our view of the relation of the position of our sun to the stars around it is similarly limited, and would change exactly in the same way if we could travel to some other star, and we would soon find that our view of the starry heavens from any one spot in space would probably be of equal value in enabling us to judge of its position as regards the whole as would the view from a top of a mountain in enabling us to decide what relation the spot on which we stood bore to the earth at large.

Our view, then, of the starry expanse around us is simply nothing more or less than a local view, and anything we find in the shape of a starry cross, triangle, circle or other figure is

merely an apparent juxtaposition of stars as viewed from one spot. This apparent juxtaposition would change its aspect altogether if the stars were viewed from some other point, and, as I have shown in my book on the Milky Way and also by the diagrams in this book, the stars in the foreground of the Milky Way would then be changed in position and removed from its zone, while others outside the zone would be brought within it. Would the stars so removed from the zone retain or lose their special brightness, and would those moved into it share in the galactic lustre? Even the luminous stream itself, if we travelled towards it anywhere would open out as we approached, while the parts we were receding from would become smaller and smaller till the general aspect of the whole would be completely changed and become quite unrecognisable after even a comparatively short journey.

It is not surprising that astronomers have been able to discover that we are somewhere near the middle of the Milky Way when it is realised that it is the densest part of the earth's shadow, in its course round the heavens, which is responsible for the phenomenon; and the further generally accepted conclusion that our sun is near the centre of the starry expanse around us would also be probably found correct, if we could travel for a trifle of, say, 10,000 light years in any direction, as we would doubtless discover that no matter where we journeyed we would continually find ourselves in the centre of the stellar expanse around us, and yet still be entirely ignorant of our real position in regard to the universal whole.

The recognition which, sooner or later, is inevitable, of the true character of the Milky Way as being simply a special shadow effect, will show that the faint clouds of closely packed stars we see in it are but a revelation of what we would find all round us in the heavens everywhere if we could see the whole sky under the same favorable influence as that which produces the Milky Way. We would then see more clearly that there is really no evidence to justify any assumption that the starry universe around us is finite in character, and it would also make it plain that we can no more define what relative position our solar system occupies among the Starry Host, than we can define what relation the point of time in which we live bears to that other unapproachable enigma, the simple line, but a line without beginning and without end, which we call Eternity.

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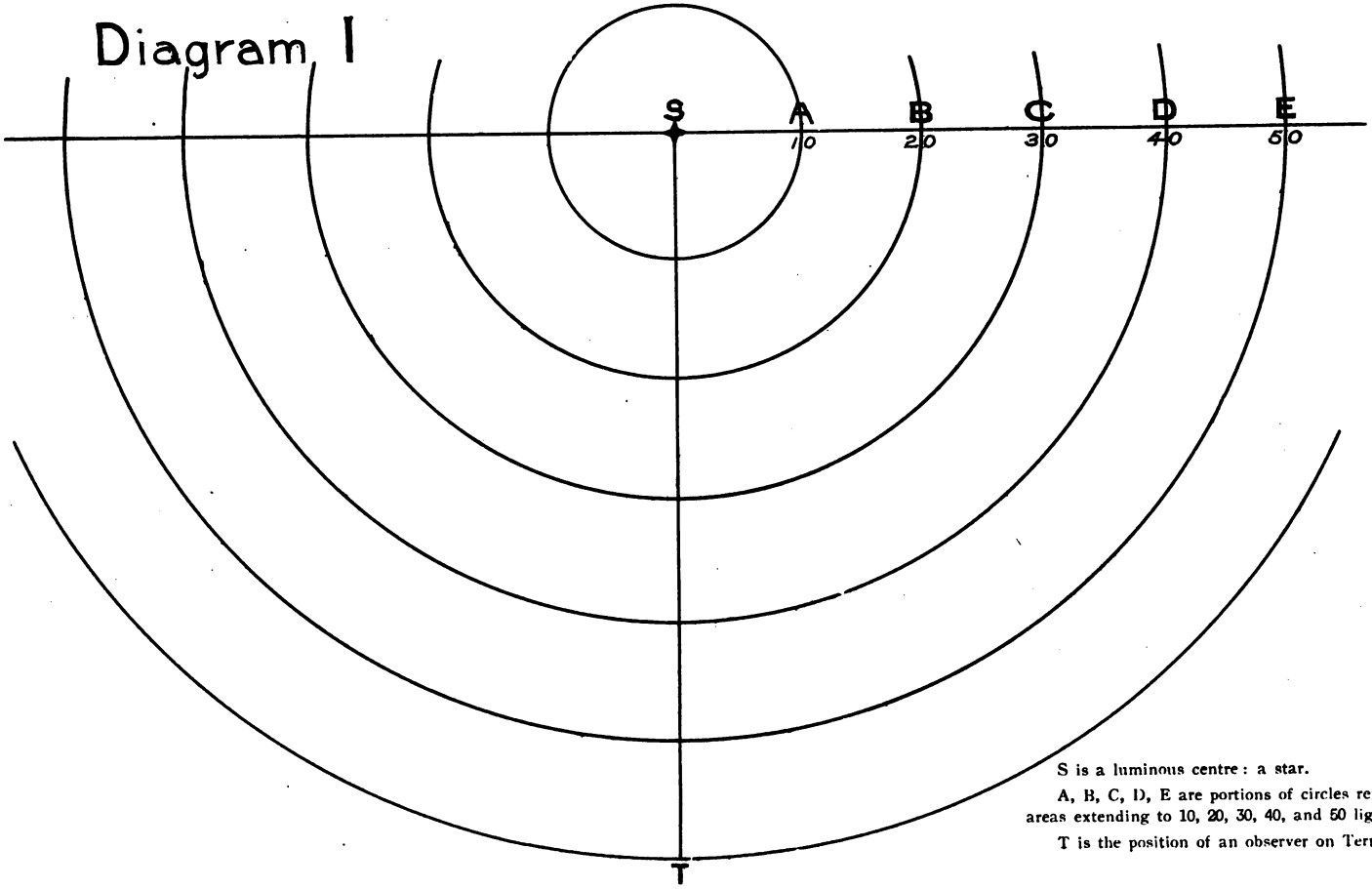
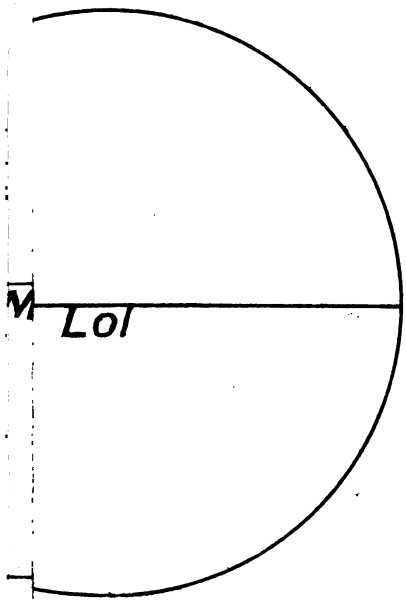
Diagram I



S is a luminous centre: a star.

A, B, C, D, E are portions of circles representing spherical areas extending to 10, 20, 30, 40, and 50 light years from S.

T is the position of an observer on Terra (the Earth).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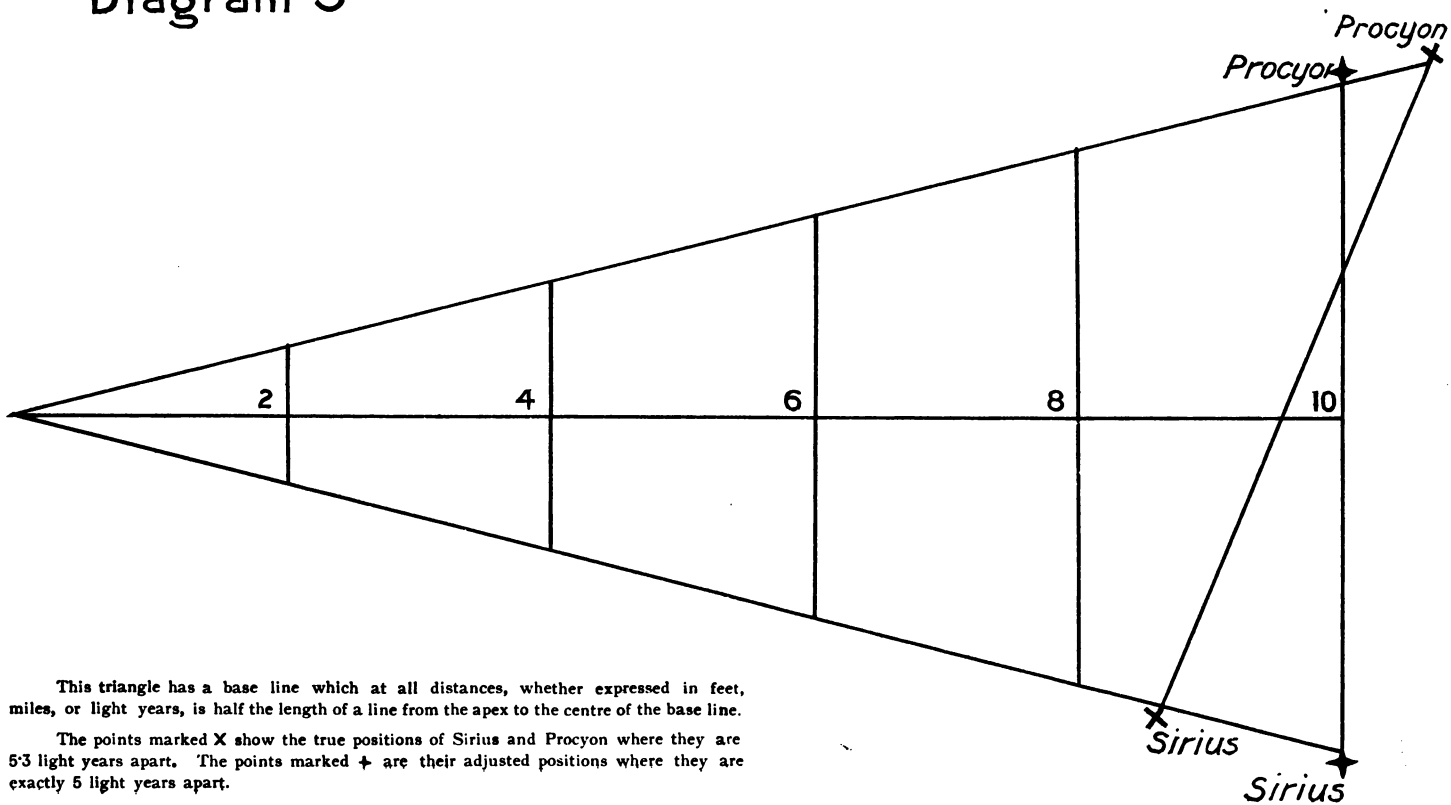
Equinoctial

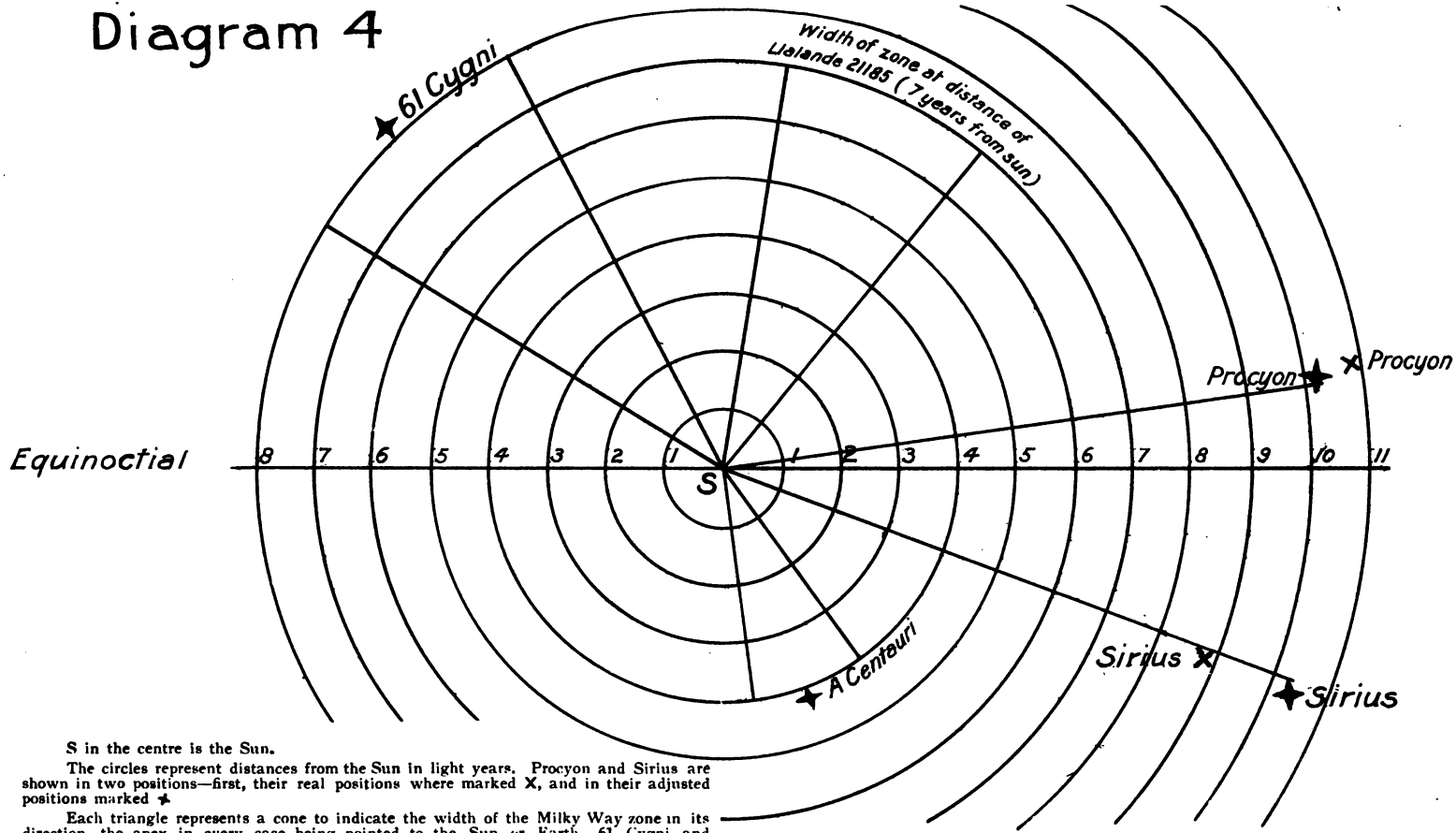
Diagram 3



This triangle has a base line which at all distances, whether expressed in feet, miles, or light years, is half the length of a line from the apex to the centre of the base line.

The points marked X show the true positions of Sirius and Procyon where they are 5·3 light years apart. The points marked + are their adjusted positions where they are exactly 5 light years apart.

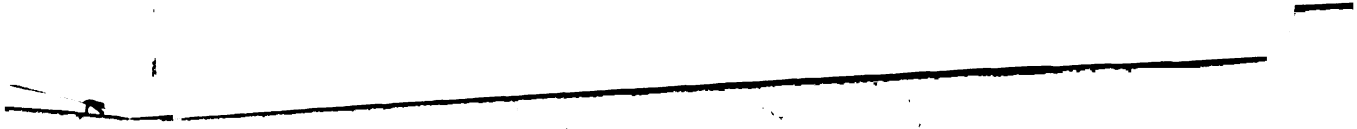
Diagram 4



S in the centre is the Sun.

The circles represent distances from the Sun in light years. Procyon and Sirius are shown in two positions—first, their real positions where marked X, and in their adjusted positions marked ✦

Each triangle represents a cone to indicate the width of the Milky Way zone in its direction, the apex in every case being pointed to the Sun or Earth. 61 Cygni and *a* Centauri are inside the cones in their direction. Procyon and Sirius are just on the edges. Llalande 21185 is well outside (above) the zone, and is not shown therefore.



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The boundaries
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Diagram 6

This diagram is intended to suggest some of the extended boundaries of the heavens which we would find in all directions if we could remove ourselves to other parts of the space around us. The boundaries shown are those which would be seen from the centres of the various circles,